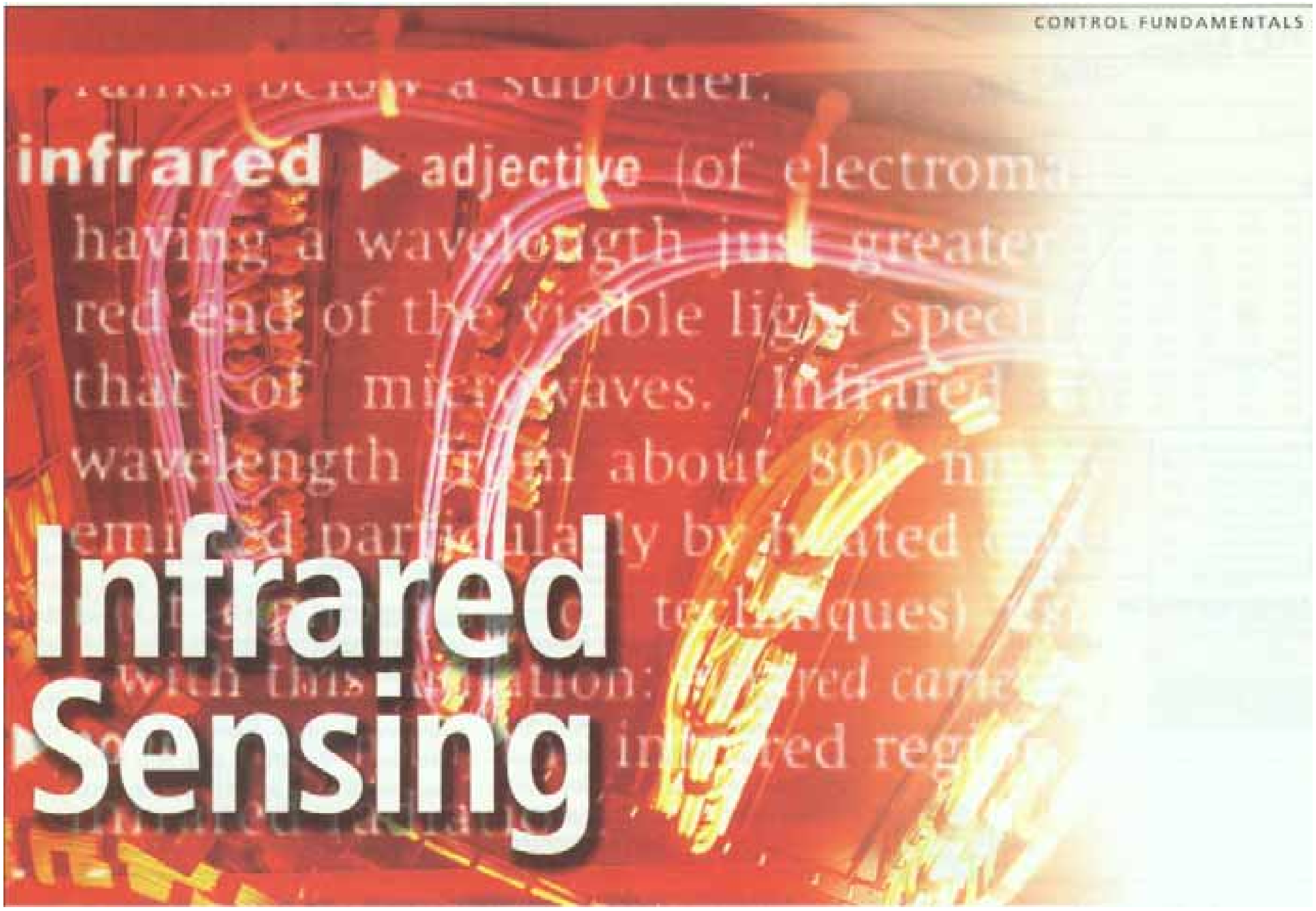


Optical flow sensors: An introduction.

By Dr. Ting-I Wang and Donn Williams

The optical flow sensor (OFS) and its predecessor, the long-baseline optical anemometer (LOA) use optical scintillation as their detection method. The LOA is a sensor that uses the same technology as the OFS but measures along much longer path lengths, 100m to 10 km.

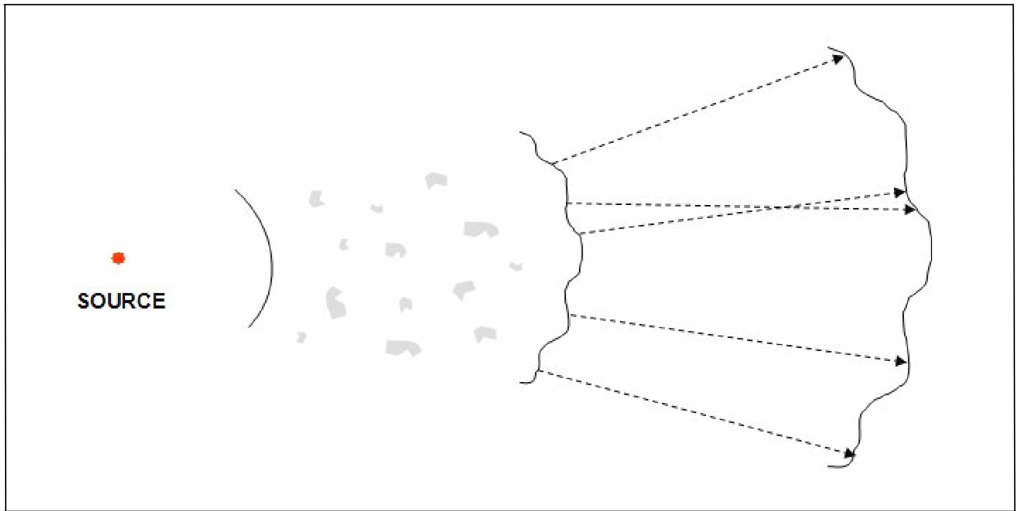
Scintillation is a general term, which describes changes in the apparent position or brightness of an object when viewed through the atmosphere. A common example of this phenomenon is the twinkling of starlight. These fluctuations occur as light passes through pockets of air with differing temperature and density, causing the refraction and scattering of the light through the non-homogenous air. By detecting the speed of movement of this scintillation, the OFS can measure air velocity in a stack or duct. You can see the mechanism of this scintillation or optical turbulence in the scintillation diagram.

The effects of scintillation of optical turbulence photographically shows the effect of scintillation or optical turbulence on a laser beam after traveling through the atmosphere. (See figure on page 82.) Instead of a uniform round disc, the turbulence breaks up and distorts the beam. The strength of the atmospheric turbulence commonly represents itself as a refractive index structure constant C_n^2. The LOA transmitter emits a modulated beam of infrared light, while the OFS uses a visible red beam (for ease of alignment). The LOA or OFS receiver detects this beam and reconverts it to an electronic signal. Intensity variations of the detected signals caused by the scintillating air parcels provide the basis of the turbulence measurement (C_n^2) for the LOA.

The amplitude of the scintillation is related to the strength of the turbulence. The twin photodiode modules in the receivers furnish the capability of measuring cross wind by detecting the temporal correlation between the two signals as the air parcels move across the beam path (covariance). The movement of the scintillation from one receiver to the next is related to the wind speed or flow rate.

Optical scintillation has a proven track record and history. It has seen use for nearly

The long-baseline optical scintillation is a sensor that uses the same technology as the OFS but measures along much longer path lengths, 100m to 10 km.



Scintillation diagram

The LOA has proven itself quite capable in measuring complex fields, which led to the EPA approving the LOA for Method 14.

30 years to measure crosswind outdoors. This same technology changed for industrial airflow monitoring in the aluminum industry. The LOA measures the air velocity along a smelting pot room roof vent typically 200-1000 m long. This is a challenging flow field to measure. There is tremendous flow variability in these vast buildings from dead zones to cyclonic to sometimes even negative flow, depending on the wind pattern directions outside.

The LOA has proven itself quite capable in measuring complex fields, which led to the EPA approving the LOA for Method 14 as an equivalent method in emissions air flow monitoring compliance rule for the aluminum smelting industry. The optical

Effects of scintillation of optical turbulence on a laser beam

anemometer sees wide use in the aluminum industry for air velocity monitoring to comply with EPA regulations. Most of the aluminum smelters in the U.S. rely on this technology to provide air velocity measurements. The EPA has also acquired LOA and used them for airflow measurements in chlor-alkali applications, similar to the aluminum smelters. The EPA considered the optical anemometer technology for other environmental airflow applications, including outdoor fence line monitoring for agriculture.

After approving the optical scintillation instrument for Method 14 equivalency, EPA officials suggested applying the optical anemometer to smokestacks for Part 60 & 75 and similar stack emissions flow sensing. As a result, they developed the OFS, which uses the same technology as the optical anemometer. The primary difference is the OFS uses smaller optics to measure across the shorter path lengths (stack diameters). Due to the technology's versatility and non-intrusiveness, the OFS can apply in a wide variety of industries and applications. Any smokestack, duct, or pipe with a minimum inner diameter of 0.2 meter, which requires an air velocity measurement, is a possible site for the OFS.

Most facilities satisfy their Part 60 & Part 75 airflow measurements via two predominant methods: Pitot tube and ultrasonic sensors. Both methods have their own strengths and weaknesses. The Pitot tube is a point measurement. Installation of the Pitot tube is simple, but flow that is not uniform, such as cyclonic or swirling, is a problem for this technology.

The ultrasonic sensor provides a more representative path-averaged measurement. But the instrument requires a costly angled installation and a path angle correction, which the lack of uniformity of flow could adversely affect. Both instruments need a purge air or blowers. Both methods are also problematic due to their intrusive nature, especially in the frequently harsh conditions.

The OFS provides a technological solution offering several advantages over more traditional methods. It can cover everything from environmental airflow compliance in power plants to the monitoring of flow rates in flare lines and stacks in the petroleum industry to flow-based process control in ducts in combustion applications.

Behind the Byline

Dr. Ting-I Wang is lead scientist and CEO at Optical Scientific, Inc. in Gaithersburg, Md. Donn Williams is vice president of the company.